Verification of the Target Acquisitions Weapons Software (TAWS) Background Water Algorithms

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1. Introduction

With the advent of "smart" bombs, there came a host of questions like, "Why did it miss this time?" In an attempt to answer this question and its preferred proactive version, "Which bomb should I use this time?" computer models have been developed over the years to forecast when weapon sensors will see the desired target. The current software in wide distribution is Target Acquisition Weapons Software (TAWS).

There are a host of factors considered by TAWS to output detection ranges and probabilities for various weapon sensors. One of these factors is the background against which the sensor will see the target. Concrete for example would look very different than a well groomed lawn, which in turn would look quite different than a large body of water. But the complexity goes beyond that, a small pond looks different than a deep lake and the mighty, muddy Mississippi river looks different than the Pacific Ocean. TAWS allows general user inputs as approximations to the actual background conditions. This project will examine the approximations in water density and water clarity for the water background in light of the data collected on this cruise.

3. Method

a. Data

Meteorological and oceanographic, observational data of interest was collected on the oceanographic cruise during 8 Aug 04 -11 Aug 04. TAWS uses a 30 hr weather data window for each target and all available data was used. Data collected outside of the normal cruise data included RADAR visibility measurements made, during the cruise by using the ships RADAR to gain distances of ships and islands that were visible from the ship. A difference between the visibility above and below the marine boundary layer was noted a few times and used in the upper air visibility weather parameter. Also used were Vandenberg AFB rawinsondes as the majority of our rawinsondes were designed to deflate by about 3,000 meters and upper air temperature and dew point averages were needed up to 15km. The Vandenberg soundings were adjusted slightly based on their agreement with a lower level average with the R/V Point Sur soundings. For example, on a 2,500m lower level average if the Vandenberg sounding was found to be 1 degree Celsius colder and 5 degrees Celsius drier than the R/V Point Sur sounding then the upper air average was adjusted by the same amount. Also, due to the undetermined dry bias of the R/V Point Sur soundings all sounding dew points were increased by 3 degrees Celsius. Cursory quality control was done on all the TAWS weather file data to insure no obvious errors existed. The weather fields used to construct the TAWS weather files are air temperature, relative humidity, sea surface temperature (SST), wind direction and speed, precipitation, aerosol type, boundary layer height, cloud amount, height and type, surface visibility, upper air visibility, and average upper air temperature and dew point.

The SPAR on the crane and the PAR on the CTD were used, at a .1 dbar interval, to obtain a ratio for light attenuation in the ocean. The PAR data from an upcast starting at 5 meters and going upwards was divided by the SPAR at the same time. Both instruments give measurements in einsteins/sec/m^2, but by doing a ratio the units drop out. CTD pressure, temperature and salinity in the same upcast were also used to calculate water density with the SEAWATER Matlab Routines by CSIRO.

For background and operational data to be input into TAWS, latitude, longitude, and time of day information was from the last CTD upcast measurement from the CTD data were used to position the ship for TAWS simulations. 4 CTD sites were used B37, B39, B52, and B54. The assumed target was a 71ft, steel, painted grey, fishing boat with engine on idle and heading of 0 degrees. In water clarity testing, a second target was also used, a 6 man raft with 2 souls on board. The IR sensor 1004 was used and assumed to be at 10000ft looking down on the target from a heading of 0 degrees.

b. TAWS algorithms for water

TAWS uses water backgrounds in three different ways, as soil moisture for vegetation and bare soil backgrounds, in the swamp/marsh background and as a water only background. The water only background is the only routine addressed here and is affected by three user inputs weather, SST and water clarity.

The algorithms for the water background work as shown in figure 1. The two

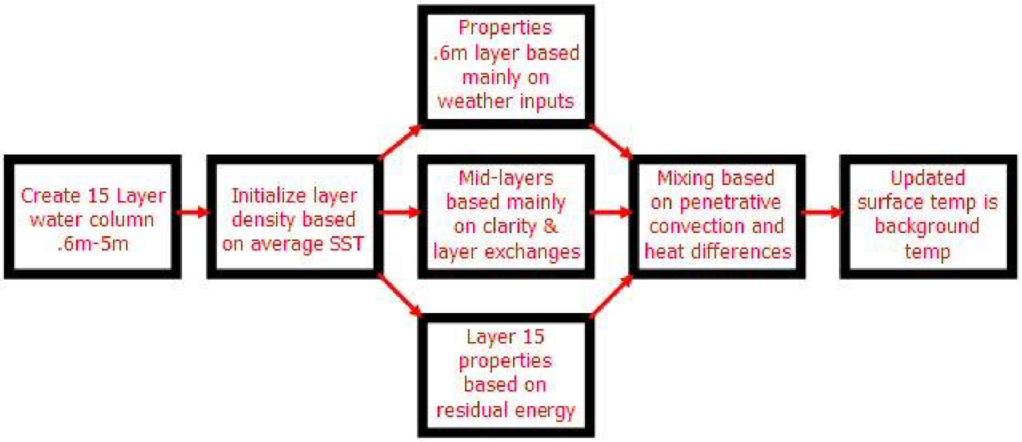

Figure 1 TAWS water background

portions that are tested in this project are first the density initialization and second the mid layer clarity calculations. First, the density is assumed to be the same for all 15 layers of the water background based on the average SST value from the 30hr TAWS weather file. The equation used is as follows: $r_v = 1000 - .019549*(ABS(T-4)^{1.68})$ with units in kg/m^3 and where T is the average SST from the weather file. It can be noted that the density cannot exceed 1000 kg/m^3 and we can conclude that this is not a seawater density calculation whose average density is 1027 kg/m^3. Therefore TAWS assumes that all water is fresh with a density close to 1000 kg/m^3. Second, the water clarity is used to determine the heat distribution from absorption of solar energy. More turbid water absorbs more heat in the top layers of the assumed water column and clearer columns transmit more energy to the bottom of the water column (5m). The user input is in fact either clear or turbid with clear having an attenuation rate at .05 and turbid having an attenuation rate of 1.00.

4. Results

Seawater density was calculated from the 4 CTD sites and found almost no variation with respect to depth. The largest change was .5 kg/m^3 or about 0.05% error. This is a respectably small error for a modeling assumption. The difference however between the TAWS fresh water density and the measured salt water density is more sizeable about 2.5%. (see Table 1) While this is not an overwhelming error, the TAWS code then uses this in 45 calculations and the subsequent variables in 433 computations. There is the possibility that the error could cancel itself or possibly grow. Access to directly inputting density to see the results of varying the density without varying the SST was not available. This feature requires more than this project to completely explain and test, but this cursory look highlights the issue.

Site	CTD Density kg/m^3	TAWS Density kg/m^3	Difference kg/m^3	Percent Error
B037	1024.3	998.6	25.7	2.509
B039	1024.2	998.6	25.6	2.4995
B052	1024	998.4	25.6	2.500
B054	1023.5	998.4	25.1	2.4524

Table 1 A comparison of computed TAWS densities and CTD measured densities on 8 Aug04-11Aug 04

Water clarity in CTD measurements averaged .81 for attenuation. The average is over all 4 sites and over all layers of each site. TAWS assigns the user input of clear, .05, or turbid, 1.00, to all layers of the water column so such an average is appropriate for comparison. The ocean was more turbid than clear in the locations. TAWS runs were done for each location for both clear and turbid conditions in attempt to determine the model's sensitivity, but the largest difference found was a difference in detection range of .2km out of 40.4 km about a .5% change. As mentioned above a different target, 6 man raft with two souls aboard, was tried, but it produced no difference whatsoever in turbid and clear conditions. This could be due to the sensor chosen, a TV or laser sensor might be more effected. Also, the cases in this project were mostly-partly cloudy possibly reducing the solar forcing so that there was too little energy for the water clarity algorithms to move around and produce a significant change.

5. Conclusion

Assuming that the density of the top 5m of ocean water, appears from this limited sampling to be a nearly perfect approximation. Using the TAWS fresh water algorithm to determine the density of sea water produces errors in the density of about 2.5%. The complexity of the TAWS code uses this erroneous density and its derivative variables 478 times. This reuse of a 2.5% error could expand the error, but access to running TAWS with forced densities would be required to accurately determine the effect on the output. Differences in water clarity barely made noticeable results using 4 different stations, two different targets, and one sensor to produce different combinations. The limited scope of this study suggests that there could some erroneous effects in water density calculations and that water clarity only played a small part in target detection range.

6. Recommendations

There are several ways to expand this study in future projects. The first is to expand the density study. This would entail gaining access to running a modified version of TAWS to determine the difference in detection range between say the fresh water algorithm, the average sea water value of 1027 kg/m^3 and measured CTD data. The TAWS water clarity portion of the study could be greatly expanded. Data from more CTD sites would give a greater range of weather and SST conditions. The use of different sensors particularly including TV and laser guided sensors could be done to see if water clarity is more a function of sensor type. Also since water clarity is used to move solar energy around in the water column a theoretical case could be added at the equator, during a 30hr cloudless period, on the day the earth is closest to the sun, at noon to see if increasing the solar forcing is what is needed to produce a difference.

7. Appendix-MATLAB code

```
%Filename = densityparser.m
%Charles M. Pearcy II, 14 Sep 04
%
%
%Purpose: Pull out the last 5-5.5 meters of CTD upcast data processed at
%.1dbars.  Compute the seawater density, compute the TAWS freshwater
%density and compute the water clarity for each .1 dbar.  Then puts it out
%in a table on the screen.
%
%Variables:  data: imported matrix of CTD data
%           top, bottom: are counters to determine how many lines of data
%           need to be processed
%           timeprime: pulls out time column from data
%           presprime: pulls out pressure column in data
%           t68prime: pulls out t90 column from data and converts it to
%           t68
%           parprime: pulls out amount of light from the par on the CTD
%           from data
%           sparprime: pulls out amount of light received at the sPAR for
%           each time from data
%           sal00prime: pulls out salinity measurements from data
%           time, pres, t68, par, spar, sal00: inverted versions of the
%           prime variables, inverted to go from .1db to 5.5db.
```

```
%        ETA: water clarity value that corresponds to TAWS ratio.
%        amount of light absorbed as opposed to transmitted.
%        SSTwxAve: Average SST from TAWS 30hr weather window. computed
%        seperately and plugged in for each different window.
%        i, counter: integer counters for do loop
%        tawsdens: TAWS density for layer (the same for all layers)
%        dens: measured density of layer as computed by sw_dens
%        table: matrix of time,pres,ETA,t68,dens,tawsdens for output display
%
%Functions used: sw_dens (which calls a number of subroutines and the
%subroutines call other sub routines Tarry finally gave me the whole
%Seawater set fron CSIRO) used to compute measured density
%
clear
data= load('b039data.txt');              %must be changed each new site
bottom = length(data(:,1));
top = bottom-55;

timeprime=data(top:bottom,1);
presprime=data(top:bottom,4);
t68prime=data(top:bottom,5)*1.00024;
parprime=data(top:bottom,10);
sparprime=data(top:bottom,11);
sal00prime=data(top:bottom,14);

time=flipud(timeprime);
pres=flipud(presprime);
t68=flipud(t68prime);
par=flipud(parprime);
spar=flipud(sparprime);
sal00=flipud(sal00prime);

ETA=1-par./spar;
SSTwxAve=16.7;                           %must be changed each new weather file
counter=bottom-(top-1);
for i=1:counter
   tawsdens(i,1)=1000-0.019549.*(SSTwxAve-4).^1.68;
end
[dens] = sw_dens(sal00,t68,pres);
clear data timeprime presprime t68prime parprime sparprime sal00prime top bottom SSTwxAve counter i
save densitycompareb039.mat              %must be changed each new site
table=[time pres ETA t68 dens tawsdens];
format short g
disp('   Time        Pressure      ETA        Temp       Density      TAWS Density')
disp(table)
```

REFERENCES

BOOK:

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Computer Resources:

Phillip P. Morgan, 1992. SEAWATER: A library of MATLAB Computational Routines for the properties of Sea Water. CSIRO Marine Laboratories, *Courtesy Tarry Rago*.

Target Acquisition Weapons Software version 3.1.3, Source Code, *Courtesy Andy Goroch, NRL.*